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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Diesel Fuel	Marine Equipment	Vehicle, Tracked
Engine (Automotive)	Oil, Engine	Vehicle, Wheeled
Fuels	Power Generators	
Gasoline	Referee Fuels	
Lubricants	Spectrometric Oil Analysis	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

~~Prescribes~~ a method is prescribed for evaluating military fuel and lubricant compatibility with Army vehicles and a method for sampling and spectrometric analysis of lubricants for symptoms of metal wear or contamination. ~~Describes~~ equipment and facilities and basic test requirements are described. ~~Provides~~ tests for octane and cetane requirements; engine, transmission, and vehicle compatibility; cold starting; and hydraulic, gear oil, and grease systems. ~~Includes~~ chart of typical fuels and lubricants for Army vehicles and equipment is included.

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US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

DRSTE-RP-702-101
*Test Operations Procedure 2-2-701 2 July 1976
AD No.

FUEL AND LUBRICANTS

1. SCOPE.

a. This TOP describes procedures for evaluating the compatibility of military fuels and lubricants with Army vehicles. Although oriented toward ground vehicles, the procedures apply also to power generators and may be adapted for marine and aircraft fuel and lubricant testing.

b. The TOP includes techniques for evaluating fuel and lubricant effects on the starting, performance, and endurance of complete vehicles and components. It includes procedures for sampling and spectrometric analysis of lubricants during development tests and endurance test phases to detect symptoms of metal wear or contamination. Guidance is provided for the use of referee and reference grade gasolines, diesel fuels, and lubricants in RD testing.

c. No attempt has been made to cover every test that can be made on a particular fuel or lubricant. From the procedures outlined, test programs can be developed to suit special requirements and to keep pace with technological advances. Excluded are warmup procedures for cold starting tests (since many of the subtests required in this phase of testing cannot be conducted satisfactorily in a cold chamber) and tests for vapor handling capability of engine fuel systems.

AD-768209

*This TOP supersedes TOP 2-2-701, 30 October 1973, including all changes.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

ITEM	REQUIREMENTS
Test course	1-Mile long, level
Field dynamometer	Deceleration and lugging
Engine dynamometer test cell	Test stand only
Prepared slopes	To accommodate vehicles to obtain data on nonlevel operation
Cold room	Capable of temperatures down to -70° F (-56.8° C) and accommodating vehicles
Teardown, gaging, and inspection facility	Sufficient size to accommodate vehicles
AOAP oil sampling kit as described in table 1, TB 43-0210 1/	Capable of withdrawing samples from crankcase
Chemical laboratory	Capable of oil analysis for wear-metals, viscosity, gravity, etc.
Control charts for elements	Must contain established comparison standards for each element involved
Oscilloscopes	5-Trace

2.2 Instrumentation.

ITEM	MAXIMUM ERROR OF MEASUREMENT*
Hygrometer	Humidity, ±2% of reading
Timing light	±0.1 second
Vacuum gage	In. Hg, ±2% of full scale
Tachometer	Rpm, ±0.5% of full scale
Magnetostriction vibration sensor	Readout is on an oscilloscope. Error of measurement not applicable
Pressure gages	Psi, ±2% of full scale

1/ TB 43-0210, Nonaeronautical Equipment Army Oil Analysis Program (AOAP), 28 August 1975.

ITEM	MAXIMUM ERROR OF MEASUREMENT*
Thermocouples with potentiometer	Temperature, ±1% of total range
Voltmeters/ammeters	Volts/amperes, ±5% of full scale
CO monitoring system	Ppm, ±5% of reading
Flowmeters	Volume, ±5% of reading
Meteorological equipment:	
Temperature	±1.0° F (±0.5° C) } or less than 2% error
Wind velocity	±1.0 mph (m/s) } or less than 2% error
Wind direction	±2.0° } or less than 2% error
Centrifuge tube (100 ml, pear-shaped)	Volume, 0.1 ml ±0.15%
Centrifuge	Speed, 1500 rpm ±100 rpm
Infrared spectrophotometer	NA

*Values may be assumed to represent ±2 standard deviations; thus the stated tolerances should not be exceeded in more than 1 measurement out of 20.

3. PREPARATION FOR TEST.

3.1 Facilities. Assure that facilities and instrumentation conform to minimum requirements.

3.2 Test Item. In test planning consider the following basic requirements but do not limit tests to these considerations which cover only the broad aspects of the investigations; design the tests to accommodate all special and unusual problems. Specific test requirements are outlined in paragraph 5.

3.2.1 Octane Numbers, Research and Motor. Be sure that the test will establish the octane number requirement of the engine model so that the engine will be satisfied by specification gasoline.

The criterion for octane requirements is the degree of knock observed during severe operating conditions. It is important to know the lowest octane number that can be used without destructive or detrimental effects. Excessive knock reduces power and produces overheating. Under some conditions the high temperatures associated with severe knock induce runaway ignition and abnormal combustion both of which cause piston destruction. The sound normally associated with knock is not in itself harmful to military vehicles.

The aural method of detecting and rating knock has been discontinued since high ambient noise levels obscured the sound and a trained observer was required.

3.2.2 Volatility at High and Low Temperatures. Provide for operation of the vehicle in both high and low temperatures to guarantee that prescribed fuel volatilities will permit starting and warmup of the engine in cold temperatures yet not cause vapor lock in high temperatures.

3.2.3 Compatibility With Engine/Fuel System.

a. Investigate whether materials in the fuel system adversely affect the fuel chemistry and whether the fuel chemistry injures the fuel system materials.

b. Insure that the oil as well as the fuel is suitable for the engine. This is of the utmost importance. Petroleum products may constitute 60 percent of a wartime supply tonnage that is shipped overseas. In times of emergency, the minimum quality permitted by specification may be the best that can be obtained. If the lubricant is unsuitable in many types of engines, a change in specification may be warranted; if the lubricant is incompatible with only one or two series of engines, however, the problem may best be corrected by engine redesign or metallurgical changes. Reports showing superior fuel and lubricant performance have the same importance as deficiency reports.

3.2.4 Specification Fuels and Lubricants.

a. Refer to appendix A for a listing of the fuels and lubricants that are most used in Army vehicles and equipment. The Army continually strives to limit the number and types of fuels and lubricants used by vehicles and other machinery in the inventory. This policy is economical from a logistics standpoint and reduces the administrative workload and number of storage facilities required to support fuel and lubricant requirements throughout the Army. Fuels and lubricants used by the DoD are identified in Federal Supply Catalog C9100-IL [2/] and TB 703-1. [3/]

b. Procurement specifications for fuels permit a range of properties with the result that all fuels are not the same. This has led to defined quality levels as indicated in appendix C. When determining quality level of fuel to be used in testing, refer to the definitions of referee and reference (standard) grade fuels in that appendix.

3.2.5 Spectrometric Oil Analysis. Metallic particles, produced primarily by friction, become suspended in the engine oil and may cause engine

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2/ Federal Supply Catalog C9100-IL, Identification List; Fuels, Lubricants, Oils and Waxes, 1 December 1971 as amended.

3/ TB 703-1, Specification List of Standard Liquid Fuels, Lubricants, Preservatives and Related Products Authorized for Use by the US Army.

component failures. Use spectrometric oil analysis as a diagnostic and prognostic aid in connection with engine malfunctions or failures, and to assist in the development of failure patterns and trends. Spectrometric oil analysis (para 5.7) is conducted in RD testing for two basic reasons: (1) as part of the Army Oil Analysis Program (AOAP), appendix B (currently this involves only the diesel 1790 engine), and (2) for special checks of engine component wear desired by the test agency or test sponsor.

3.3 Instrumentation. Install instrumentation as required for each subtest.

3.4 Data Required.

3.4.1 Test Course. Location, type of surface, grade (e.g., level), length, straightness, smoothness.

3.4.2 Test Item. Fuel/lubricant description, specification number.

3.4.3 Instrumentation. Type, nomenclature, accuracy, and location for each piece of instrumentation.

4. TEST CONTROLS.

4.1 Referee Grade Fuels. Use referee grade fuels (as opposed to reference grade fuels - see definitions in app. C) in all RD testing when available.

NOTE: Dod Directive 4140.43 4/ states: "It is the objective of the Department of Defense to reduce to a minimum the number of fuels required in the Military Logistics System and to increase the flexibility for use of fuels which are readily available worldwide" and, to achieve this objective, "equipment operating characteristics should be such as to permit full operation with a minimum of restrictions on fuel properties." Consequently, a duty incumbent on the RD community is to ascertain by adequate testing that no fuel-related problems will occur in fielded equipment. Using referee grade fuels is a positive step toward this goal.

a. Use referee grade gasoline (MIL-G-46015A 5/), when available, in research, development (DT I through DT III), and proof testing of spark-ignition engines, ground-based turbine engines, generators, vehicle heaters, etc.

4/ DoD Directive 4140.43, Department of Defense Liquid Hydrocarbon Fuel Policy for Equipment Design, Operation and Logistic Support, 5 December 1975.

5/ MIL-G-46015A (MR), Gasoline, Automotive, Combat, Referee Grade.

b. Use referee grade diesel fuel (MIL-F-46162A 6/), when available, in research, development (DT I through DT III), and proof testing of all compression-ignition engines, diesel-powered auxiliary units, gas turbine engine driven mobile electric power generators, etc.

4.2 Identification of Fuel in Reporting. To eliminate any uncertainty as to the type fuel that was used in testing, indicate the specification number and title in all reports covering test items that burn fuel (e.g., vehicles, generators, etc.)

4.3 Reference Grade Oils. Use reference grade oils (see definition in app. C) in research, development (DT I through DT III), and proof testing unless specifically directed otherwise.

NOTES: 1. Automotive engine lubricants are qualified using laboratory dynamometer acceptance tests that define specific performance criteria (i.e., sludge protection, high temperature diesel dispersancy, antimist properties, etc.). The candidate product generally is qualified after meeting all five (in the case of MIL-L-2104C 7/) performance tests. The probability of a single qualified product having borderline or marginal performance in all five tests is remote. Because of this unlikelihood of developing a true referee engine oil (with the attendant problems of supply), reference grade products were established for use.

2. Reference grade engine oils are used in RDTE programs to insure against any potential lubricant-oriented engine malfunctions. The specific reference oil is designated by the specification custodian through the publication of various specifications (see app. A, table 2) or by the test sponsor. Since fuel (in terms of volume consumed and quality) has a greater influence than lubricant on engine performance, the use of referee fuel outweighs the need for referee engine oil. Moreover, since fuels are not "qualified" as are lubricants prior to procurement, their importance with respect to test control (referee specification) becomes more significant and necessary.

4.4 Compatibility Factors. Determine the compatibility of fuels and lubricants with Army vehicles and components (and with power generators) under actual use conditions either in a vehicle or on a full-scale engine operated on a laboratory dynamometer. Analyses of fuel and lubricant chemical, physical, and performance properties for compliance with lubrication orders, which are made before the tests covered in this TOP, can serve as guides to the suitability of the materiel.

4.4.1 Engine, Fuel, and Lubricant Compatibility. Fuel, lubricant, and engine must demonstrate compatibility as a group to be effective. Knock or pre-ignition, certain deposit conditions, localized wear areas, or chemical reactions can limit the useful life of an engine. These conditions

6/ MIL-F-46162A (MR), Fuel Diesel, Referee Grade.

7/ MIL-L-2104C, Lubricating Oil, Internal-Combustion Engines, Tactical Service.

can be caused by either the fuel, the lubricant, the design and metallurgy of the engine, or a combination of these factors.

4.4.2 Lubricant-Component Compatibility. Vehicle components require petroleum products for many purposes. Transmission, servo systems, and hydraulic systems, for example, may use oil as a power transmission fluid as well as for an antiwear, antifriction, anticorrosion, or heat transfer agent. All lubricants, whether classified as greases or as hydraulic, preservative, or gear oils, must be tested in the vehicle component under actual service conditions to assure that all the requirements demanded of the lubricant by the project manager or sponsor are fulfilled.

4.5 Climatic Factors. Different petroleum materials are usually prescribed for use under intermediate and extreme climatic conditions; evaluate each and report lubrication problems in detail to cover the prescribed climatic range. 8/ Conduct the fuel and lubricant tests before or in conjunction with other development tests. While concurrent testing may minimize costs, before participating be sure that basic fuel and lubricant investigations will not be subordinated to other test objectives.

4.6 Analysis of Used Oil. AR 750-43 9/ formalizes the application of the AOAP which, since 1962, has been used to reduce Army aircraft losses due to engine failures. The spectrometric oil analysis and physical tests and chemical tests prescribed in the AOAP provide fast, precise quantitative determination of wear-metals and contaminants in used lubricants, and the results provide a diagnostic aid for detecting lubricated parts wear and induction of dust or water into lubricants, establishing overhaul periods, evaluating prescribed operating intervals between maintenance actions (or extending such intervals), and assisting in trouble-shooting activities.

4.7 Safety. To insure the safety of personnel and equipment, all activities described in this TOP will be conducted in strict compliance with the requirements of DARCOM Regulation 385-100, 10/ TOP 2-2-508, and applicable local operating procedures.

5. PERFORMANCE TESTS.

5.1 Octane Requirements, Research and Motor. As stated in paragraph 3.2.1, octane requirements are indicated by the degree of knock observed during severe operating conditions. Varying degrees of knock for military vehicles are rated as follows:

Rating	Definition
O	Clear, absence of knock
A	Trace knock
B	Tolerable knock
C	Severe or destructive knock

8/ CCL Report 316, A Predictive Study for Defining Limiting Temperatures and Their Application in Petroleum Product Specifications, Fort Belvoir, VA, Coating and Chemical Laboratory, November 1972.

9/ AR 750-43, Test, Measurement, and Diagnostic Equipment, 24 July 1975.

10/ DARCOM-R 385-100, Safety Manual.

These ratings denote only the amplitude or severity of knock, regardless of frequency of occurrence. An isolated B or C knock is not considered when rating an engine.

5.1.1 Method.

a. Mount a magnetostriction vibration sensor on the engine cylinder head so that the sensor output is fed into an oscilloscope. A standard oscilloscope may be used for air-cooled engines, but a synchronized multiple trace scope is best adapted to liquid-cooled engines.

b. Introduce fuels of known octane into the engine and observe the oscilloscopic trace patterns for combustion and knock phenomena under various conditions of full throttle and fuel load as described below. Use full boiling gasolines having the type of severity needed for research/motor octane number requirement ratings. Full-boiling reference gasolines are available and in use by industry. These are available through the Coordinating Research Council (CRC) and should be identified. An example is provided in SAE Paper 750937, "Octane Number Increase of Military Vehicles Operating on Unleaded Gasoline." Various commercial fuels of known sensitivity may also be used (complete procedures are contained in APG Miscellaneous Reports 11/).

c. Conduct the tests (1) with the engine installed in the vehicle, under field conditions where cooling and power train characteristics are the predominant factors; and (2) with the engine on a test stand where variables such as timing and intake air temperature are under laboratory control and can thus provide the data required to accurately predict the effects of these variables. For complete analysis as influenced by vehicle installation all four methods below are required; the investigation may be limited, however, to one or two of the tests for reasons of expediency or economy. The four methods of loading or absorbing the output of the vehicle are:

(1) Level Road Acceleration - Accelerate the vehicle without external load from minimum to maximum speed at full throttle in a given gear or transmission range. Record engine speeds when knock appears and when it disappears for various octane number fuels. Based on these values, prepare a curve indicating the maximum requirement of the engine (fig. 1).

(2) Deceleration - Decelerate the vehicle from maximum to minimum speed in a given ratio using an externally applied load (i.e., power absorption trailer or field dynamometer). Record observations as in (1) above.

(3) Lugging - Operate the vehicle at full throttle at a series of constant speeds using a field dynamometer or power absorption trailers or both to apply the load. Record the degree of knock for each fuel for each engine speed.

11/ APG Miscellaneous Reports: 258, Procedures for Determining the Octane Requirements of Military Engines; 259, Procedures for Conducting Tests Involving Cold Temperature Rooms; 260, Procedure for Inspection and Gaging of Internal-Combustion Engines; 261, Procedures for Conducting Laboratory Dynamometer Test of Reciprocating Internal-Combustion Engines; Aberdeen Proving Ground, MD.

Vehicle Make ________________ Model ________________ No. __________

Engine Make ________________ Model ________________ No. __________

Type of Test ________________ Test Date ________________

Avg. Bar. _______ Avg. Ambient Temp. _______ Avg. Hum. _____ Deposit Hours ___

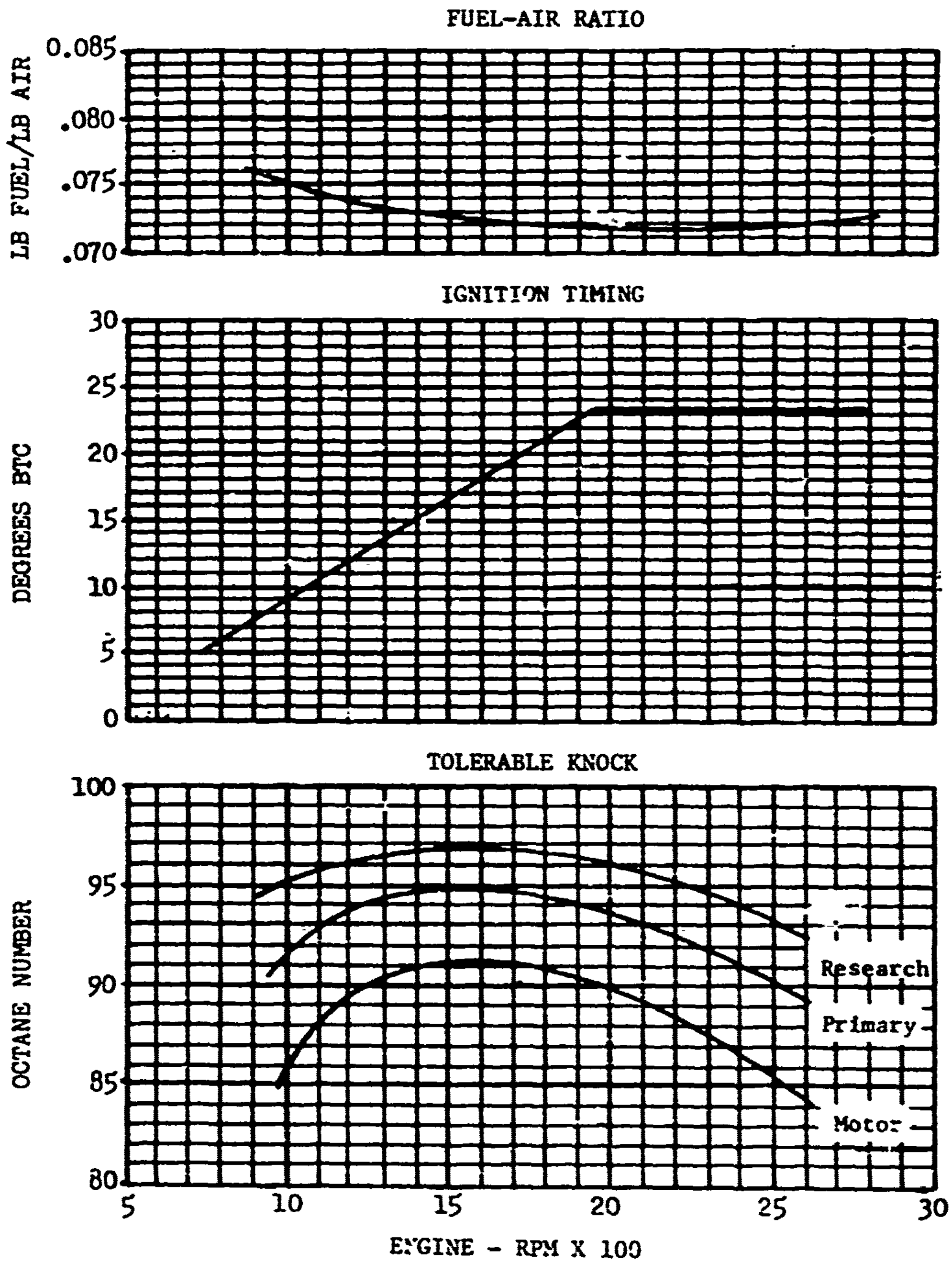

Figure 1. Octane Requirement Test (Research or Motor).

(4) Test Stand - This method corresponds to (3) above. Follow the same procedure except use an engine absorption dynamometer to control load and speed.

5.1.2 Data Required.

a. Engine speed - knock in and knock out for acceleration and deceleration test.

b. Fuel octane number (research or motor).

c. Gear range - acceleration lugging and deceleration only.

d. Meteorological data.

e. Load - dynamometer and lugging only.

f. Temperature - spark plug gasket, air intake, coolant, oil.

g. Fuel pressure.

h. Fuel-air ratio.

i. Ignition timing - spark advance.

j. Vehicle miles or operating hours.

k. Knock intensity at speed.

l. Fuel specification/type.

m. Manifold vacuum.

n. Nomenclature, type, and identification numbers of the item.

5.2 Cetane Requirements. The cetane requirement is the ignition quality of a diesel fuel in terms of the ASTM cetane number (ASTM procedure D613). The cetane number is obtained by comparison of the ignition quality of the test fuel with the ignition quality of blends of fuels of known cetane numbers under standard operating conditions. The test is usually performed at a qualified laboratory such as the one (of several maintained by the Army) at US Army General Materiel and Petroleum Activity, Petroleum Field Office (East), ATTN: STSGP-PE, New Cumberland Army Depot, New Cumberland, PA 17070.

5.2.1 Method. Use an ignition quality test unit consisting of a single cylinder engine of continuous variable compression ratio, with suitable loading and accessory equipment and instruments, mounted on a stationary

base. Refer to the ASTM Manual 12/ for specific engine, equipment, and operating conditions and procedures.

a. Vary the compression ratio for the sample and each fuel to obtain a fixed "delay period," that is, the time interval between the start of injection and ignition.

b. When the compression ratio for the sample is bracketed between the ratios for two fuel blends differing by not more than five cetane numbers, calculate the rating of the sample by interpolation.

5.2.2 Data Required.

a. Engine speed.

b. Ignition timing.

c. Injector operating pressure.

d. Injection quantity (volume).

e. Injection pump setting.

f. Injector pintle valve lift.

g. Valve clearances.

h. Compression ratio adjustment.

i. Crankcase oil viscosity.

j. Temperatures - injector water jacket, oil, coolant, intake air.

k. Oil pressure.

l. ASTM cetane number - the whole number nearest to the value - determined by calculation from the percentage by volume of normal cetane (= 100) in a blend with heptamethylnonane (HMN, = 15) - that matches the ignition quality of the test fuel when compared by this method. To obtain the cetane number insert the matching blend percentages to the first decimal in the following equation:

$$\text{Cetane number} = \%\ \text{n-cetane} + 0.15\ (\%\ \text{HMN})$$

5.3 Compatibility With Engines and Transmissions. Investigate vehicle engine and transmission compatibility with the prescribed fuels and lubricants during routine development and endurance tests conducted in the field or in the laboratory.

12/ ASTM Manual for Rating Motor, Diesel, and Aviation Fuels, American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103.

5.3.1 Method. A field test requires the test courses listed in TOP's 2-2-506 and 2-2-507 and shop facilities for teardown and gaging. For a laboratory test an engine dynamometer and test cell are required. There must also be access to a petroleum laboratory.

a. Use referee grade fuels and reference grade lubricants (paras 4.1 and 4.3). Referee grade lubricants or experimental grades are used only under special direction. Refer to appendix A for fuel and lubricant specifications.

b. Conduct laboratory tests as part of an endurance test or apply TOP/MTP 2-2-700. This procedure provides for disassembly, inspection, gaging, and weighing of critical parts before and after operation in accordance with an appropriate endurance operating schedule. The schedule may follow the standard 500-hour acceptance test cycle with loads progressively increased; the more severe, accelerated, 240-hour tracked vehicle engine test cycle or 210-hour wheeled vehicle engine test cycle; 13/ or any other test cycle prescribed for compatibility testing. To obtain the required critical condition maintain engine oil and coolant temperatures at the maximum or minimum levels needed. Analyze samples of new and used oils for changes in chemical and physical characteristics. Take samples intermittently for limited analyses and at scheduled oil changes for complete analyses (para 5.7).

c. For an economical method of establishing field conditions, install a gaged engine or transmission in a vehicle undergoing extensive endurance testing; be sure, however, to maintain a comprehensive record of engine loading. Use essentially the same gaging and inspection procedures as are used for test stand operation. 14/

5.3.2 Data Required. A complete listing of data is given below. Select those elements that are applicable to the scope and objective of the test.

5.3.2.1 Dynamometer Test Stand.

a. General: Engine speed, dynamometer scale reading, fuel consumption, oil consumption, and blowby.

b. Pressures:

Oil: gallery, to and from cooler.
Crankcase.
Fuel at carburetor or injection pump.
Air cleaner restrictions.

13/ CRC Report, Development of Military Fuel/Lubricant/Engine Compatibility Test, Coordinating Research Council, Inc., 30 Rockefeller Plaza, New York, NY.

14/ APG Miscellaneous Reports 260 and 261 (see footnote 11, p. 8).

Intake manifolds: before and after supercharger when required.
Exhaust manifold.
Barometric.

c. Temperatures (°F or °C):

Air inducted into the engine.
Cylinder heads: all spark plugs.
Water to and from coolers and gallery.
Oil to and from coolers and gallery.
Exhaust gas: each cylinder on diesel engines.
Manifold temperatures (intake - before and after supercharger as required).
Wet and dry bulb.
Cooling air to and from engine.
Fuel.

5.3.2.2 Oil Analyses (Both New and Used Oil). Conduct the analyses in accordance with standard procedures listed in FED-STD-791 15/ and ASTM Standards on Petroleum Products. 16/

a. Viscosity (at 210° and 100° F or 98.9° and 37.8° C) and centistokes.

b. Viscosity index (calculation).

c. Pentane and benzene insolubles, normal and coagulated (used oils only).

d. Total acid and base number.

e. Ramsbottom carbon residue.

f. Sulphated residue.

g. Dilution (used oils only).

h. Pour point (new oils only).

i. Flash point.

j. Additive metals (zinc, calcium, boron, potassium, sodium, barium, and magnesium).

k. Wear and contaminant metals (iron, copper, lead, chromium, molybdenum, nickel, boron, sodium, and silicon).

l. Gravity, °API.

15/ FED-STD-791, Lubricants, Liquid Fuels, and Related Products; Methods of Testing.
16/ ASTM Standards on Petroleum Products, American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103.

5.3.2.3 Gasoline and Diesel Fuel Analyses.

a. Distillation.

b. Reid vapor pressure.

c. Sulfur.

d. Lead (antiknock compound).

e. Gum content.

f. Octane number (research and motor).

g. Gravity, °API.

h. Flash point.

i. Cloud point.

j. Pour point.

k. Viscosity.

l. Cetane number.

m. Ash content.

n. Carbon residue (ASTM procedure D524).

5.3.2.4 Physical Inspection for Wear (Before and After Operation). 17/

a. Dimensional:

All crankshaft journals and crankshaft bearing bores.
Connecting rod bearing bores.
Piston pin and piston pin plug length.
Piston ring side clearance.
Damper weight pin bore and pin diameter.
Piston outside diameter (OD).
Main and connecting rod bearing inside diameter (ID).
Piston pin bore ID.
Valve stem OD, valve guide ID.
Damper hub pin bore.
Valve clearance, valve timing.
Magneto timing.
Spark plug gap.
Cylinder bore.
Piston ring gap.

17/ APG Miscellaneous Report 260 (see footnote 11, p. 8).

Crankshaft end play.
Injector timing, injector nozzles.

b. Weights: Piston rings and bearing inserts (main and rod).

5.3.2.5 Visual Inspection for Wear and Deposits (Aft Operation). Conduct these inspections in accordance with CRC Manua 1 and 5 which also provide procedures for evaluating wear deposits, sc .ffing, etc.[18]

a. Ring sticking: ring deposits (carbon and lacquer) on top, inside diameter, and bottom.

b. Ring face condition.

c. Piston surface deposits on top, combustion chamber, under head, skirts, relief areas, and lands.

d. Piston ring groove deposits on top, back, bottom, and drain holes (percent blocked) and piston groove inside diameter (percent of ring containing carbon).

e. Piston surface condition on top land, skirt, and piston pin.

f. Valve deposits on head, face, tulip, and stem.

g. Valve surface conditions to include freeness in guide, head, face, seat, stem, and tip.

h. Tappets, cams, rocker arms, and push rods to include tappet deposits, tappet surface condition, and condition of cam lobes.

i. Rocket arm condition to include tip, bushing, shaft, and push rod.

j. Cylinders to include cylinder head deposits, cylinder deposits in ring travel area and above and below ring travel, and cylinder surface condition in ring travel area and below.

5.4 Compatibility With Vehicles.

5.4.1 Method.

a. Unless specifically directed otherwise by the test sponsor, use referee grade fuels (when available) and reference grade lubricants obtained through routine purchases and the following test facilities and instrumentation:

(1) Prepared slopes.

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[18] CRC Manuals 1, Gasoline Engine Rating Manual and 5, Diesel Engine Rating Manual, Coordinating Research Council, Inc., 30 Rockefeller Plaza, New York, NY.

(2) Gunner's quadrant.

(3) Pressure gages.

(4) Thermocouples with potentiometer.

(5) Tachometer.

(6) Petroleum Laboratory.

b. Observe the ability of the system (e.g., fuel pump, diaphragms, fuel lines, gaskets, etc.) to handle fuels at any vehicle operating angle.

c. Determine the efficiency and serviceability of filters, fuel tank cleanliness, and suitability of materials. Copper and high copper content alloys, for example, should not be permitted to come in contact with modern fuels. The catalytic effect of copper on gasoline causes gum formation.

d. Special tests are not usually required to determine the compatibility of power trains and other components with recommended lubricants. Identify the materials used and note any significant findings during endurance testing.

e. When possible, record fluid temperatures and pressures and engine and vehicle speeds under all critical operating conditions; i.e.: at maximum speed, minimum speed, and maximum torque; on longitudinal and lateral slopes; and at creeping speeds. It is particularly important to monitor the temperatures in hydraulic transmissions since the prevailing practice is to use engine oils in transmissions of the fluid coupling and converter type. Since high viscosities contribute to excessive power loss and higher temperatures, lower viscosity materials such as grade 10 and arctic lubricants have had the widest use. Hydraulic oils of low viscosity may also be used. In general, engine oils remain stable for continuous operations at temperatures up to 250° F (121° C) and for intermittent operation at temperatures up to about 275° F (135° C).

5.4.2 Data Required.

a. Fluid pressures, psi or kPa.

b. Fluid temperatures, °F and °C.

c. Ambient temperatures, °F and °C.

d. Engine and vehicle speeds, rpm and mph or kilometers per hour.

e. Slope angle, percent.

f. Specification designation of fuels and lubricants.

5.5 Cold Starting.

5.5.1 Method. To determine the suitability of petroleum materials for use under both intermediate and extreme cold climatic conditions, follow the cold starting and warmup test procedures given in TOP/MTP 2-2-650. (The standards for acceptability are given in the ROC, DP, or specification.) Conduct the tests using referee grade fuels sampled before the start of cold room testing. Use the following facilities and instrumentation:

a. Cold room.

b. Oscillograph - five traces minimum.

c. Voltmeters, ammeters.

d. Thermocouples - pyrometer, potentiometer.

e. Spare batteries - two sets minimum.

f. Battery charger and slave kit.

g. Arctic clothing.

h. CO monitoring system.

i. Pressure gages.

5.5.2 Data Required.

a. Continuous recording on oscillograph to include cranking speed, cranking current, battery voltage, time trace, and heater voltage (if so equipped).

b. Cold soak temperatures and intervals.

c. Fuel and lubricant identification data.

d. Date and time test started.

e. Starting procedure.

f. Comments on performance of components during starting.

g. Periodic readings of temperatures during engine warmup and subsequent heater operation.

h. Battery electrolyte specific gravity.

5.6 Hydraulic, Gear Oil, and Grease Systems.

5.6.1 Method.

a. Drain, flush, and refill the system with the test fluid. (For a more complete test, disassemble, inspect, and gage the system before adding the test fluid.) When possible, install thermocouples to measure critical temperatures of oils, greases, or components. For hydraulic systems install pressure gages to measure operating pressures and pressure drops across filters. If required, install flowmeters to measure pump output.

b. After a suitable break-in period, opeate the system on a cycle designed to simulate actual operating conditions. Record temperatures and pressures for each condition. Closely observe performance to determine whether:

(1) Operating parameters prescribed in the DP, specification, or other guidance document are being met.

(2) Fluid temperature adversely affects operation.

(3) Excessive leakage occurs.

(4) Relief and check valves perform adequately.

c. Analyze samples of new and used fluids to determine stability and deterioration. Maintain logs of operating conditions. Following the tests, disassemble and inspect components for wear, scuffing, discoloration, overheating, deterioration of seals, sludging, and similar effects.

5.6.2 Data Required.

a. Operating hours.

b. Operating conditions.

c. Fluid consumption rates.

d. Temperature, °F or °C.

e. Pressure, psi or kPa.

f. Flow rate, gallons or liters per minute.

g. Fluid makeup (chemical and physical).

5.7 Spectrometric Oil Analysis. The procedures given below are those required by the AOAP. If samples are obtained for other reasons (see para 5.8), follow the same sampling technique but not the same schedule.

5.7.1 Method.

5.7.1.1 Sampling - General. A reliable oil sample is one that is truly representative of the circulating oil in the major assembly being evaluated for rate of wear. Correct sampling procedures are therefore important. Use the sampling procedures as outlined in TB 43-0210 19/ or as agreed upon with the Army Maintenance Management Center (AMMC). As a minimum, take oil samples as follows:

a. Before operations (take initial new oil samples from each batch received by the test activity).

b. At specific intervals between oil changes as specified in the approved procedure for the AOAP.

c. Before and immediately after every oil change.

d. Under conditions specified in paragraph 14, TB 43-0210.19/

NOTE: While contaminants may become heavily concentrated at points where sludge collects and in oil filters, many investigators believe that sufficient amounts of contaminant will remain suspended in the lubricant to permit detection and evaluation. This does not, however, rule out the need to examine portions of the material collected in the filters when the examination of the lubricant itself leaves doubt.

5.7.1.2 Sampling Techniques.

a. Take sample while the assembly is warm. The equipment should be at operating temperature to insure that circulating oil has reached a uniform consistency. Complete DA Form 3253 (Used Oil Sample Information) for each sample. Wrap the completed form around the sample and secure it with a rubber band.

b. Use the "tube method" or "drain method" as described in TB 43-0210 to obtain samples. Although variations may become necessary due to the configuration of the test item, follow the cleanliness and homogeneity requirements for taking samples as indicated in TB 43-0210.

5.7.1.3 Oil Analysis. The oil analysis is usually conducted by the Army laboratory designated by the AMMC (app. B). Sometimes, however, analyses may be permitted in-house. The specific method to be used for determining wear-metals concentration depends upon the type of analyzer on hand. Several now available in the DoD operate on the principle of atomic emission, atomic

19/ See footnote 1, p. 2.

absorption, or X-ray fluorescence. All are capable of measuring the concentration of wear-metals or contaminants in parts per million (ppm) levels. Use the manufacturer's instructions to operate the system and obtain the desired data. At the Materiel Testing Directorate, Aberdeen Proving Ground, a direct reading emission spectrometer is used. It is currently programmed to detect simultaneously and record sequentially iron, silicon, chromium, magnesium, silver, copper, aluminum, tin, lead, and nickel in the 0 to 500 ppm range. These elements were selected as the metals usually most indicative of internal wear found in lubricating oils. Different elements may be selected for analysis as applicable depending on the item being tested. It is planned to add molybdenum, zinc, boron, phosphorous, calcium, barium, and titanium.

Hold oil filters, when changed, for additional information should the oil sample analysis leave doubts. Examine deposits removed from the filter as required.

5.7.2 Data Required.

a. Component life, hours or miles/kilometers.

b. Vehicle nomenclature, model, and other identifying data.

c. Date.

d. Oil added since last sample.

e. Grade and specification No. of oil.

f. Reason for sampling.

g. Wear-metals in lubricant (ppm).

h. AOAP laboratory results and analysis.

i. Description of material picked up by the filter if examined.

5.8 Additional AOAP Laboratory Analyses. When specifically directed to do so, supplement the spectrometric oil analysis with laboratory tests of the oil to determine physical and chemical properties.

5.8.1 Method. Using general laboratory procedures, analyze the oil to determine the following as applicable:

a. Total insolubles.

b. Total water.

c. Total acid/base.

d. Fuel dilution/breakdown/oxidation/polymerization (IR spectroscopic analysis).

e. Kinematic viscosity.

5.8.2 Data Required.

a. Volume of insolubles to the nearest 0.01 ml and any unusual solid matter.

b. Percent water to the nearest 0.1 percent.

c. Neutralization number (acid or base) reproducible within 15 percent of the neutralization number.

d. Spectrographs of new and used oil analyzed.

e. Kinematic viscosity in centistokes, measured to the nearest 0.7 percent of the mean value of the test runs made on the same oil.

f. Comparison of (used and unused oil) filter spots as to size of spot, carbon content, water, visual appearance.

6. DATA REDUCTION AND PRESENTATION.

6.1 Octane Requirements. Tabulate and plot all data in the manner shown in figure 1 (para 5). Determine and report the compatibility of the engine with the prescribed fuels. Point out in the report any discrepancies.

6.2 Cetane Requirements. Compare the test results on the sample fuel with the results on blends of fuels until the sample is bracketed. Establish the cetane number by interpolation and report to the closest integer.

6.3 Compatibility With Engines and Transmissions. Analyze the lubricants for changes in chemical and physical characteristics (para 5.7). Base the degree of component, fuel, and lubricant compatibility on wear, deposits, scuffing, corrosion, etc., together with their effects on engine performance. Refer to CRC Manuals 1 and 5 (see footnote 17, p. 15) for procedures for making these evaluations. The results of dynamometer engine testing may or may not be representative of field operation; correlate these data with data from field operation when possible.

6.4 Compatibility With Vehicles. Note and report significant findings such as malfunctions or marginal performance attributable to fuel or lubricant.

6.5 Cold Starting. Note and report malfunctions or marginal performance incidents attributable to fuel or lubricant.

6.6 Hydraulic, Gear Oil, and Grease Systems. Report (a) abnormalities noted during the tests, (b) results of fluid analysis indicating deterioration or contamination (para 5.7), and damage to components found during final inspection.

6.7 Spectrometric Oil Analysis.

a. Compare the types and levels of various wear-metals detected in the used oil samples with those measured in the new oil samples and with the composition of the assembly under investigation. Compare the amount of the element in the used oil sample with an established value of the element which reflects the amount expected for normal wear. The rate of increase in concentration of various wear-metals, versus hours or miles of operation, can be used to predict an abnormal wear situation. Crankcase, transmission, and gearbox oils tested at intervals indicate the wear-metals trend. The wear-metals trend can be interpreted to signal three possible actions: check the unit, overhaul the unit, or replace the unit. Abnormal increases in the level of elements are indicative of excessive metallic wear and incipient failure. Repair or replacement of worn parts at this time could prevent damage to the entire assembly or mechanical system. Use AOAP laboratory results and analyses and include them in the final report.

b. Abnormal levels of sodium or boron in the sample indicate leakage of engine coolant (antifreeze) into the engine lubricating oil. High levels (720 ppm) of silicon in lubricants signify dust ingestion and, in the case of the engine, indicate poor air filtration due to air cleaner malfunction or leaks in the air induction system; in gearbox lubricant, faulty seals or vent valves are the probable causes.

c. Compare the results of the oil filter analysis with the results of the oil analysis to assure that contaminants in the filter have been detected in the oil. Attempt to determine the reason for the adulterants in the filter.

d. Store the data accumulated to provide a data bank useful in subsequent tests on similar components as a means of establishing or refining the standards for construction of control charts used as a maintenance diagnostic tool.

6.8 Additional AOAP Laboratory Analyses. Compare the results obtained from analysis of used oil samples with the results of analysis of new oil samples (comparison method depending on the specific analysis made) to show any abnormal changes occurring in the oil being used. Assess the changed properties to predict impending engine malfunctions or mechanical failures; identify leaking seals; detect potential corrosion, overheating, the presence of coolants, or the need for preventive maintenance or oil change; and for other adverse evidence.

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APPENDIX A
TYPICAL FUELS AND LUBRICANTS FOR ARMY VEHICLES AND EQUIPMENT

Table 1 - Fuels

Type	Applicable MIL/FED Spec	Use
Fuel Oil, Diesel	Fed Spec VV-F-800B	DF-A, Arctic Grade: In high-speed automotive type diesel engines and in pot-type burner space heaters in ambient temperatures lower than -25° F (-31.7° C). (Do not use for slow-speed stationary engine applications.) DF-1, Winter Grade: In high-speed automotive service in ambient temperatures as low as -25° F. May be used for medium speed, stationary engines where fuel heating facilities are not available. DF-2, Regular Grade: In all automotive high-speed diesel engines and in medium-speed engines in temperatures above +20° F (-6.7° C).
Fuel, Diesel, Referee Grade	MIL-F-46162A (MR)	In research, development, and proof testing of all compression-ignition engines, diesel-powered auxiliary units, gas turbine engine driven mobile electric power generators, and other fuel handling supply items. This fuel should not be used in engines or other equipment in the field as a substitute for VV-F-800 diesel fuel without approval of the engine manufacturer or the US Army Mobility Equipment Rearch and Development Command, ATTN: DRXFB-GL, Fort Belvoir, VA 22060.
Gasoline, Automotive	FED Spec VV-G-76B(1)	Regular Grade: In spark-ignition engines in normal service and when specified by the equipment manufacturer. Premium Grade: In spark-ignition engines in severe service and when specified by the equipment manufacturer.
Gasoline, Automotive	MIL-G-3056D	Type I: For general purpose at all temperatures above 0° F. Type II: Where mean temperature is consistently below 32° F (0° C).

Table 1 - Fuels (Continued)

Type	Applicable MIL/FED Spec	Use
Gasoline, Automotive, Combat, Referee Grade	MIL-G-46015A (MR)	In research, development, and proof testing or qualification of spark-ignition and ground-based turbine engines, components, vehicle heaters, etc. Not to be used in engines or other equipment as a substitute for MIL-G-3056 gasoline unless approved by Coating and Chemical Laboratory, Fort Belvoir, VA.
Gasoline, Automotive	Fed Spec VV-G-001690	Special Grade: In 1971 (or later) commercial and administrative vehicles equipped with the lower compression ratio spark-ignition engines. Regular Grade: In spark-ignition engines designed to operate with a gasoline of this octane or when required by equipment manufacturer recommendation. Premium Grade: In spark-ignition engines designed to operate with a gasoline of this octane or when required by equipment manufacturer recommendation.
Gasoline, Unleaded	Fed Spec VV-G-109A	In stationary internal combustion engines and as fuel in gasoline pressure appliances.
Turbine Fuel, Referee	MIL-T-5161H	In testing all types of aircraft engines that are designed to operate on jet engine fuel conforming to MIL-T-5624 and ASTM D-1655.
Turbine Fuel, Aviation, Grades JP-4 and JP-5	MIL-T-5624J	In testing aircraft turbine, ramjet, and rocket engines.
Fuel, Navy Distillate	MIL-F-24397 (SHIPS)	For fleet use in designated marine power plants.
Fuel Oil, Diesel, Marine	MIL-F-168846	In diesel engines in submarines and for such other uses as may be specified at temperatures above 30° F (-1.1° C).

Table 2 - Lubricants

Type	Applicable MIL/FED Spec	Use
Lubricating Oil, Compounded	MIL-L-15019C	In special applications, e.g., worm gears or wick feeds.
Lubricating Oil, Internal Combustion Engine, Administrative Service	MIL-L-46152	Grade 10W, 30, 10W-30, 20W-40: For crankcase lubrication in administrative vehicles and light to medium duty trucks operating under manufacturer's warranty in ambient temperatures above -20° F (-29° C).
Lubricating Oil, Internal Combustion Engine, Tactical Service	MIL-L-2104C	Grade 10, 30, 40, 50: In crankcases of reciprocating spark- and compression-ignition engines of all types of tactical ground equipment and in high speed, high output, supercharged compression-ignition engines in all ground equipment in temperatures above -20° F (-29° C).
Lubricating Oil, Internal Combustion Engine, Preservative and Break-In	MIL-L-21260B	Grade 10, 30, 50: For preservative and breakin use in reciprocating spark-ignition and compression-ignition engines, in all types of ground equipment at ambient temperatures above -20° F (-29° C). Type I (grade 10, 30, 50) oils are used in all spark-ignition and compression-ignition engines operating at output levels up to 150 psi, BMEP. Type II (grades 10 and 30) oils are used only in supercharged compression-ignition engines operating at output levels of approximately 150 psi, BMEP and above and are not used in spark-ignition engines.
Lubricating Oil, Shipboard Internal Combustion Engine, High Output Diesel	MIL-L-9000G	Used in advanced design, high-output, shipboard main propulsion and auxiliary diesel engines using fuel conforming to MIL-F-16884.

Table 2 - Lubricants (Continued)

Type	Applicable MIL/FED Spec	Use
Lubricating Oil, Reciprocating Compressor, Ground Support	MIL-L-26087B	Grade II: In high compression, reciprocating air compressers at ambient temperatures from 25° to 140° F (-3.9° to +60° C). Grade I: 5° to 130° F (-15° to +54° C).
Lubricating Oil, Preservative, Medium	MIL-L-3150B	In lubrication of ferrous and nonferrous metals, interiors of gear assemblies, transmission, differentials, etc., against corrosion; not for use in protection of internal combustion engines.
Lubricating Oil, General Purpose, Low Temperature	MIL-L-7870A	Used wherever a general purpose, low temperature, lubricating oil is required, particularly where an oil of low evaporation, possessing rust protective properties is desired.
Lubricating Oil, Refrigerant Compressor	Fed Spec VV-L-825A	For lubrication or compression units of refrigeration equipment operated on sulfur dioxide refrigerant.
Lubricating Oil, Hydraulic and Light Turbine	MIL-L-17672B	Used in steam turbines, hydraulic systems, water turbines, waterwheel-type generators, hydraulic-turbine governors, and in other applications where a high grade lubricating oil having anticorrosion and antioxidation properties is required.
Lubricating Oil, Steam Turbine (Noncorrosive)	MIL-L-17331F (Ships)	Used in main turbines and gears, auxiliary turbine installations, certain hydraulic equipment, general mechanical lubrication, and air compressors.
Lubricating Oil, Gear, Multipurpose	MIL-L-2105B	Grade 80 90 140 Used in automotive gear units, heavy duty industrial-type gear units, steering gears, and fluid-lubricated universal joints of automotive equipment.

Table 2 - Lubricants (Continued)

Type	Applicable MIL/FED Spec	Use
Lubricating Oil, Gear, Sub-Zero	MIL-I-10324	Lubrication of automotive gear units, heavy duty industrial-type enclosed gear units, steering gears, universal joints of automotive equipment operating in ambient temperatures ranging from 0° to -65° F (-18° to -54° C).
Lubricating Oil, Internal Combustion Engine, Arctic	MIL-L-46167	For crankcase lubrication of reciprocating spark-ignition and compression-ignition engines used in all types of ground equipment in ambient temperatures in the range of +40° to -65° F (+4° to -54° C). Required for Dod generator sets (DED).
Grease, Automotive and Artillery	MIL-G-10924C	Lubrication and surface corrosion protection of all automotive and artillery equipment operated over the temperature range -65° to +225° F (-54° to +107° C). This grease may also be used in other applications within this temperature range where an NL6I No. 2 consistency grease with oxidation resistant and corrosion preventive properties is desirable. The grease is not intended for use on machinery that comes in contact with foods.
Hydraulic Fluid, Petroleum Base, for Preservation and Operation	MIL-H-6083D	As a preservative medium for aircraft hydraulic systems and components and as an operational preservative fluid for ordnance equipment, such as recoil mechanisms and hydraulic systems for rotating weapons or aiming devices. It may be used in wide temperature (-65° to +275° F) (-54° to +135° C) applications depending upon the operational parameters of the system.

Table 2 - Lubricants (Continued)

Type	Applicable MIL/FED Spec	Use
Hydraulic Fluid, Rust Inhibited, Fire Resistant, Synthetic Hydrocarbon Base.	MIL-H-46170	In recoil mechanisms and tank hydraulic systems. For use in the M60 series tanks. If used in other combat vehicles, a study should be made to determine its applicability in such systems, particularly in the area of seal compatibility and low temperature operability. The fluid is rust inhibited and may be used as a preservative medium for hydraulic systems and components.
Lubricating Oil, General Purpose, Preservative (Water Displacing, Low Temperature)	VV-L-800A	Lubrication and protection against corrosion of certain small arms and automatic weapons, and whenever a general purpose, water displacing, low-temperature lubricating oil is required (check MIL Spec for more detail).

APPENDIX B
ARMY OIL ANALYSIS PROGRAM (AOAP)

1. The AOAP is a program for determining the concentrations of various metallic elements in an engine oil sample by means of emission or absorption spectroscopy primarily to detect the presence of abnormal amounts of wear-metals in that sample which could indicate the potential failure of components containing those metals. The objectives are as follows:

a. To detect incipient component failure by means of changes in trace amounts of elements in the lubricant.

b. To reduce maintenance costs through preventive maintenance efforts prior to major repair as indicated by symptomatic techniques.

c. To obtain a 3-day oil analysis response time for nonaeronautical equipment to prevent costly repairs.

d. To develop a data bank of information relating component wear or failure to the levels of various elements in the lubricant.

e. To provide additional information from the lubricant analysis for correlation with results of the component inspections conducted (para 5.3 and TOP 2-2-700) after laboratory and endurance testing to investigate the relationship of component deterioration to changes in the amounts of various elements in the lubricant.

2. The AOAP was established by AR 750-43 (ch 4) [20/] which states that all installations and activities will participate as outlined in the applicable technical publications consistent with the policies and objectives outlined in AR 750-43. TB 43-0210 [21/] provides guidance for participating in the AOAP. Other arrangements between TECOM and AMMC could override TB 43-0210 relative to specific procedures

3. DARCOM has directed that all TECOM test activities having the diesel 1790 engine initiate the AOAP for these engines. It is anticipated that additional equipment in RD testing may be added to the AOAP as the program expands. While TB 43-0210 provides a sampling schedule (every 25 hours of operations or every 30 days whichever comes first), the sampling schedule sampling procedures may be changed as agreed upon between TECOM and the AMMC.

20/ See footnote 9, p. 7.
21/ See footnote 1, p. 2.

4. It is customary in the AOAP to send the samples to the nearest laboratory commissioned by the Army to perform such analyses at no cost to the sender. In the case of APG, the nearest location is:

Chief, US Army General Materiel and
Petroleum Activity
Petroleum Field Office (East)
ATTN: STSGP-PE
New Cumberland Army Depot
New Cumberland, PA 17070

5. Before the AOAP for a specific engine can be successful it is necessary to obtain baseline data on the types and levels of metallic deposits that are preludes to engine component failures. TECOM participates in this "baseline data" phase, and will presumably be expected to participate in the final AOAP phase.

APPENDIX C [22]
DEFINITIONS

Army Oil Analysis Program. A coordinated, Army-wide effort to detect impending equipment component failures through analytical evaluation of oil samples, formerly referred to as the Army Spectrometric Oil Analysis Program (ASOAP).

Calibration standard. A liquid, with controlled viscosity and flash point, containing precisely controlled quantities of specified metallic elements for calibrating and standardizing spectrometers.

Certification. The process of evaluating an oil analysis laboratory's capability to perform oil analysis services.

Correlation samples. A test sample prepared for monitoring the accuracy and analytical capability of a laboratory.

Evaluation criteria. Factors, including quantitative expressions of wear-metals, against which the results of a spectrometric oil analysis are compared to determine the condition of the component in question and the necessity for recommending corrective action.

Oil. A liquid lubricant or transfer fluid such as engine oil, transmission oil, or hydraulic fluid.

Oil analysis. A test or series of tests which provide an indication of equipment component condition by applying a method of precision detection and quantitative measurement of wear-metals in an oil sample, and which may include physical property testing of the sample.

Referee grade fuel. A fuel that represents the minimal or marginal quality level that can be procured under the parent specification while meeting all specification requirements. It is tailored to be the equivalent of what might be available in times of national emergency. This fuel, now procurable under special specifications (see table 1, app. A), is of minimum quality not only from the standpoint of octane or cetane values, but also with respect to volatility, additives, and dirtiness that could affect an engine's endurance characteristics.

Referee grade lubricant. A lubricant that would represent the minimal or marginal quality level that could be obtained under the parent specification while still meeting all specification requirements.

Reference grade or standard fuel. A fuel that represents the average or above-average quality level that is usually obtained when procurement is made under the parent specification.

22/ Source: AR 750-43 (footnote 9, p. 7) excluding definitions of referee and reference grade fuels and lubricants.

Reference grade lubricant. A lubricant that represents the average or above-average quality level that can be obtained under the parent specification.

Response time. That interval which encompasses the sampling operation, sample delivery and analysis, evaluation of analytical results and communication of oil analysis facility recommendations to the appropriate unit.

Spectrometric oil analysis. A method of determining the concentrations of various chemical elements in an oil sample by means of emission or absorption spectroscopy primarily to detect the presence of abnormal amounts of wear-metals in that sample which could indicate the potential failure of components containing those metals.

Wear-metals. Metallic particles, produced primarily by friction, which are suspended in a used oil.